



Jet Propulsion Laboratory
California Institute of Technology



Flight-Experiment Validation of the Dynamic Capabilities of a Flux-Pinned Interface as a Docking Mechanism

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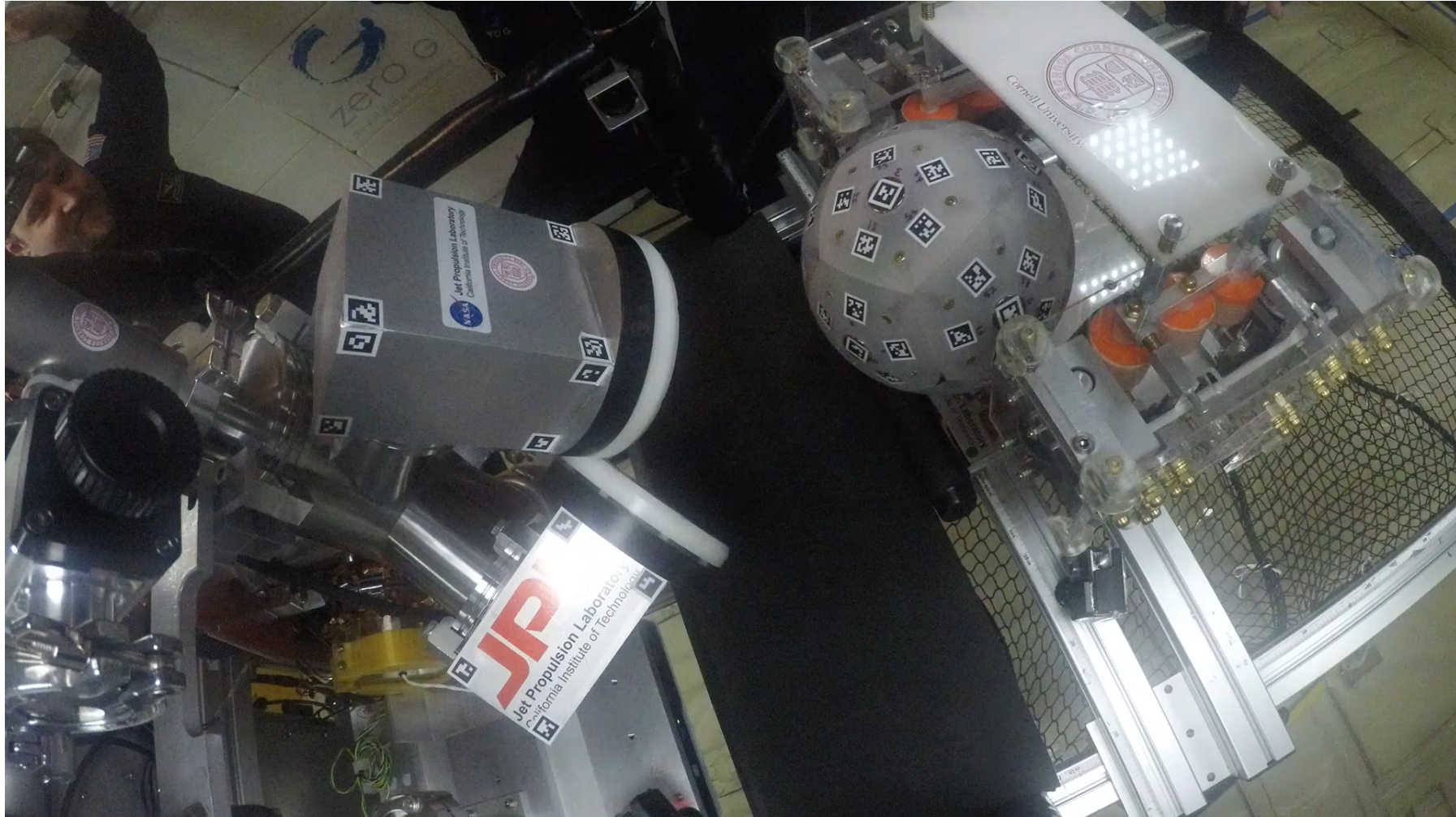
Mars Sample Return Concept



Mars Sample Return Concept



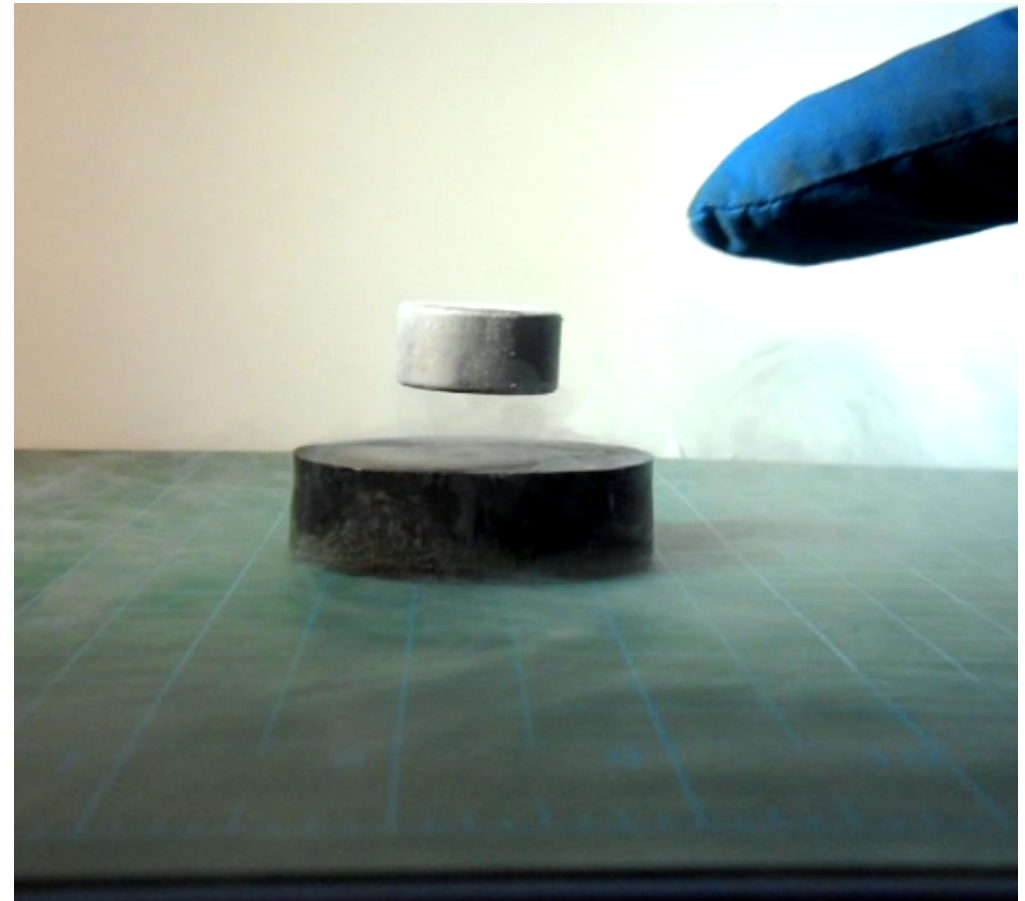
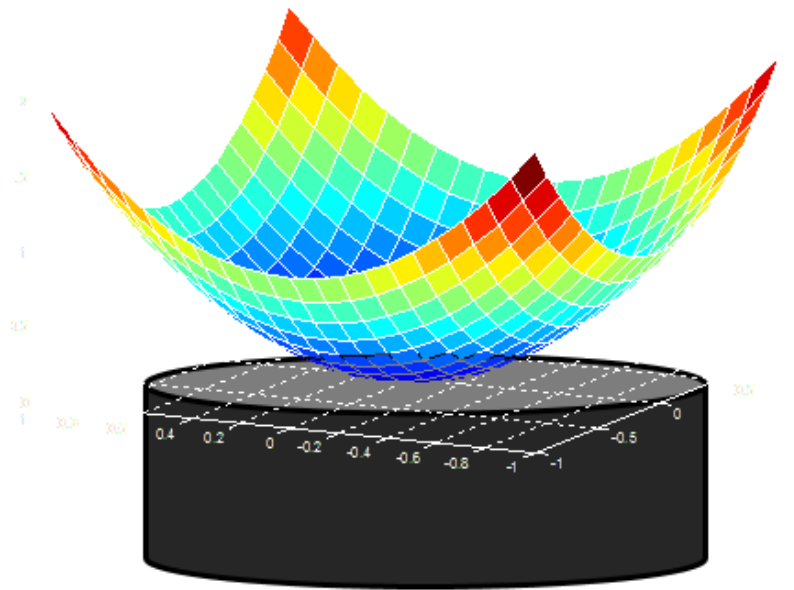
Capture and Docking with Flux Pinning



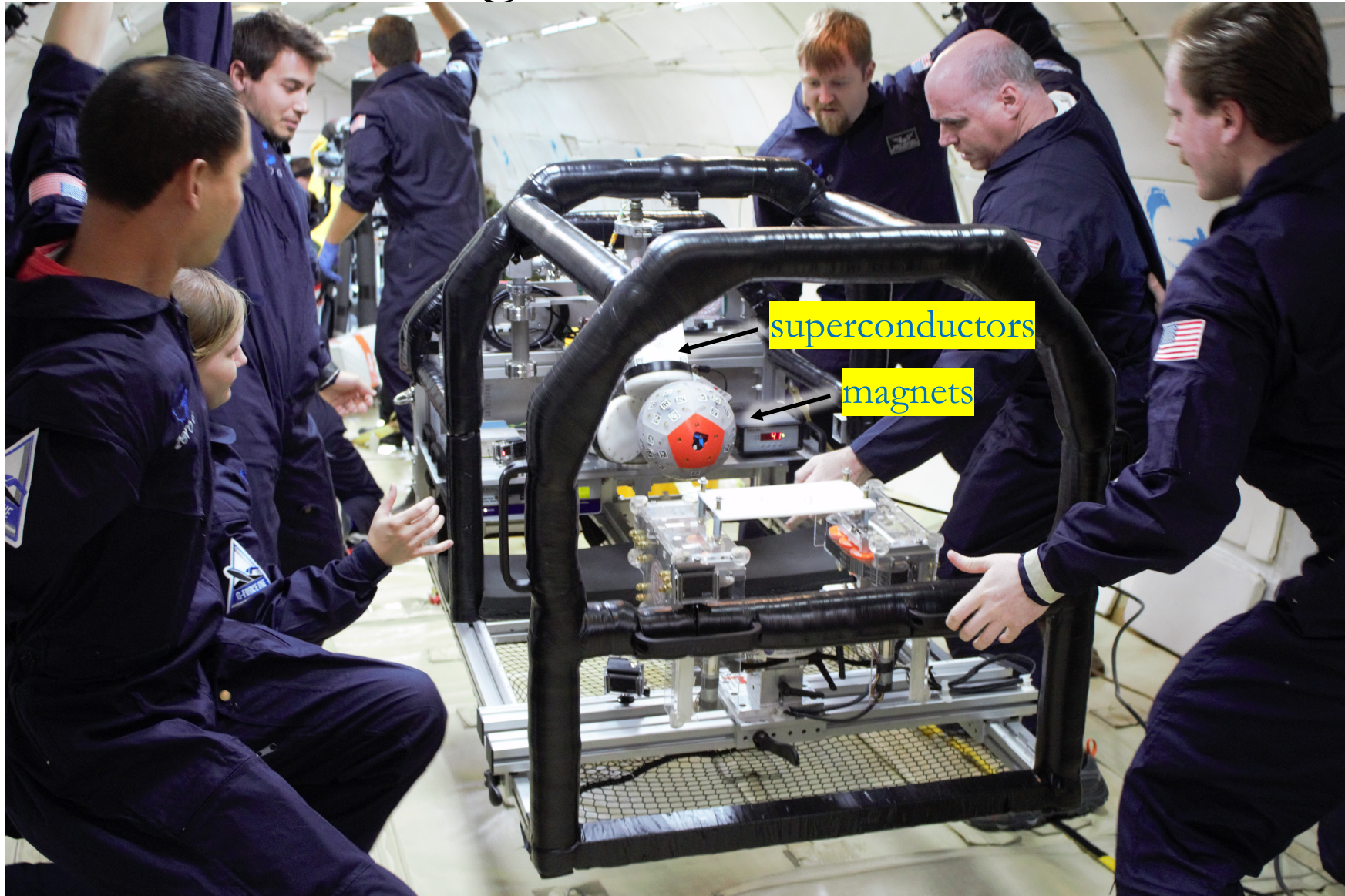
To Take Away

- Flux Pinning Physics
- Microgravity Experiment
- Dynamic Metrics
- Dynamic Capabilities

Flux Pinning Basics



Experiment Configuration



Sensors



Metrics to Characterize Interface

Given a range of initial states and the sensor measurements:

- Capture success at various energetic states
- Contact force upon collision
- Interface stiffness
- Settling time

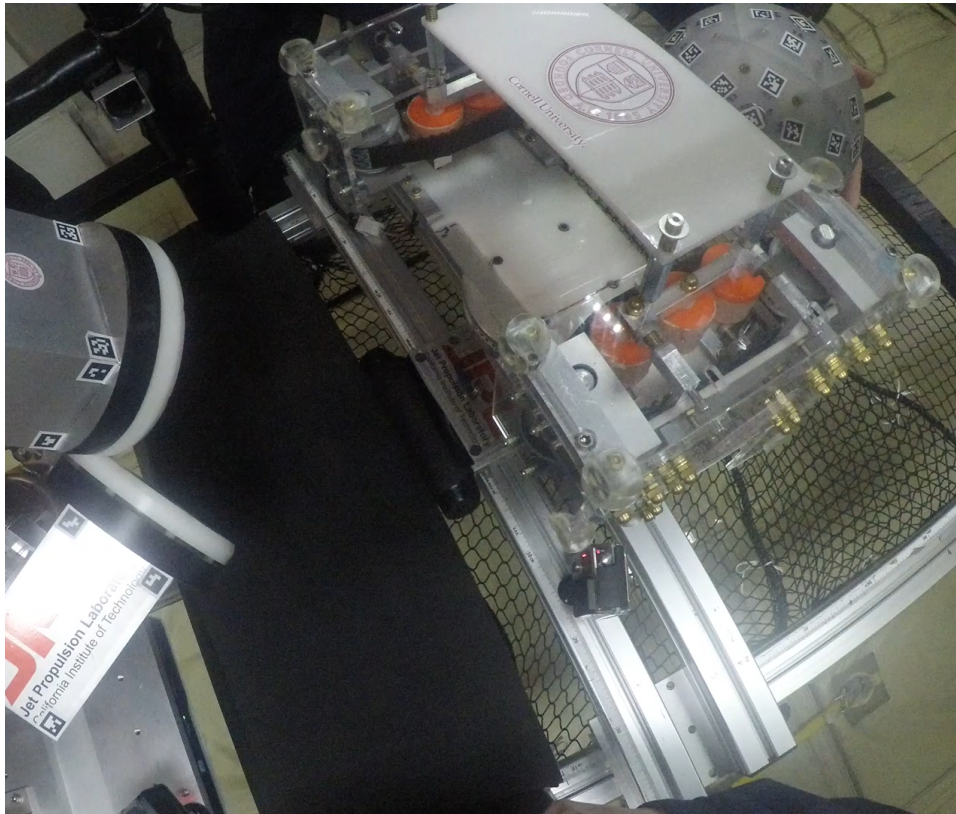
Microgravity Experiments

- An experiment from each capture scenario in which:

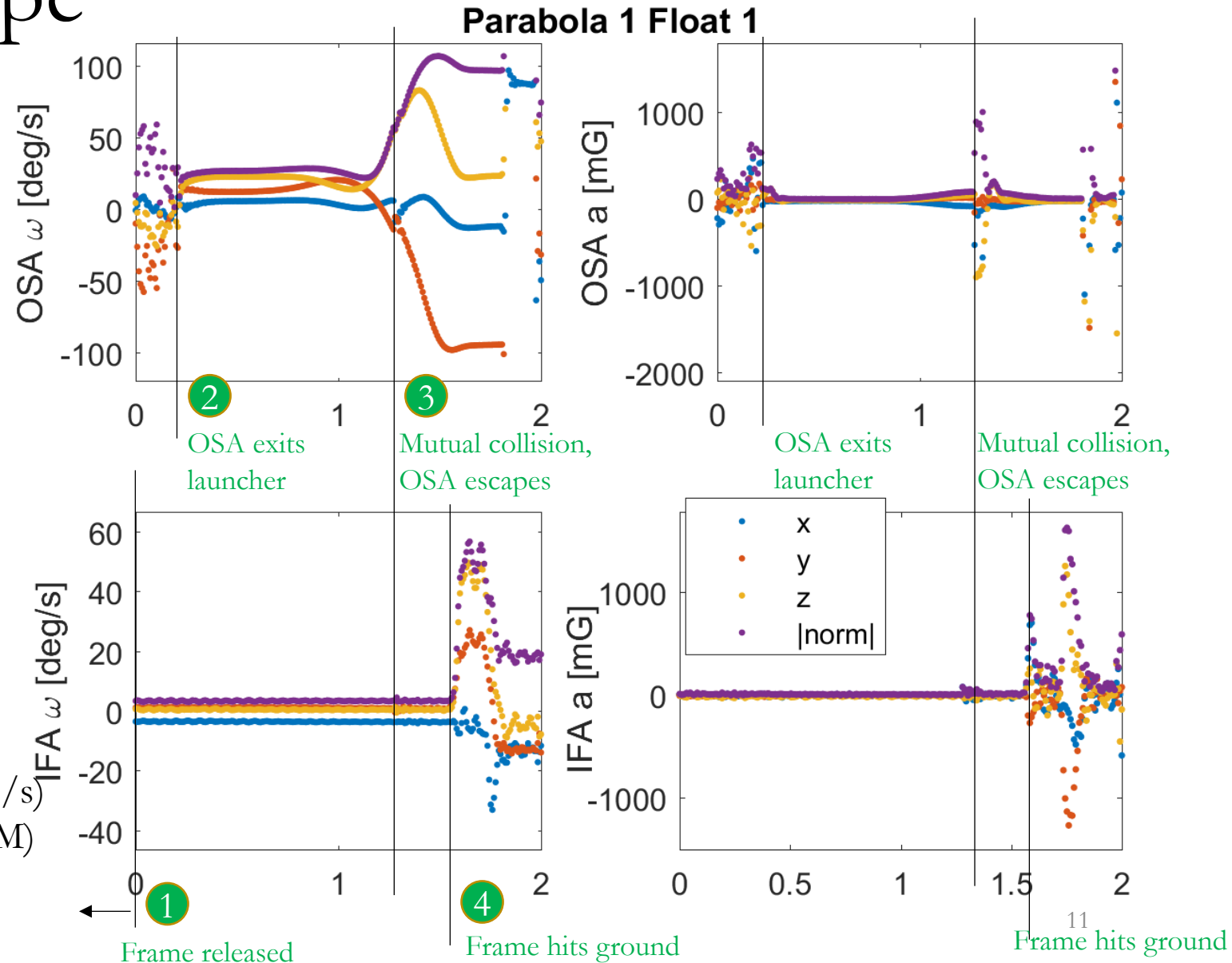
Outcome Matrix	Capture	Escape
No Contact	Most Desirable	Less Desirable
Contact	More Desirable	Least Desirable

- Equilibrium experiment with near-zero initial motion

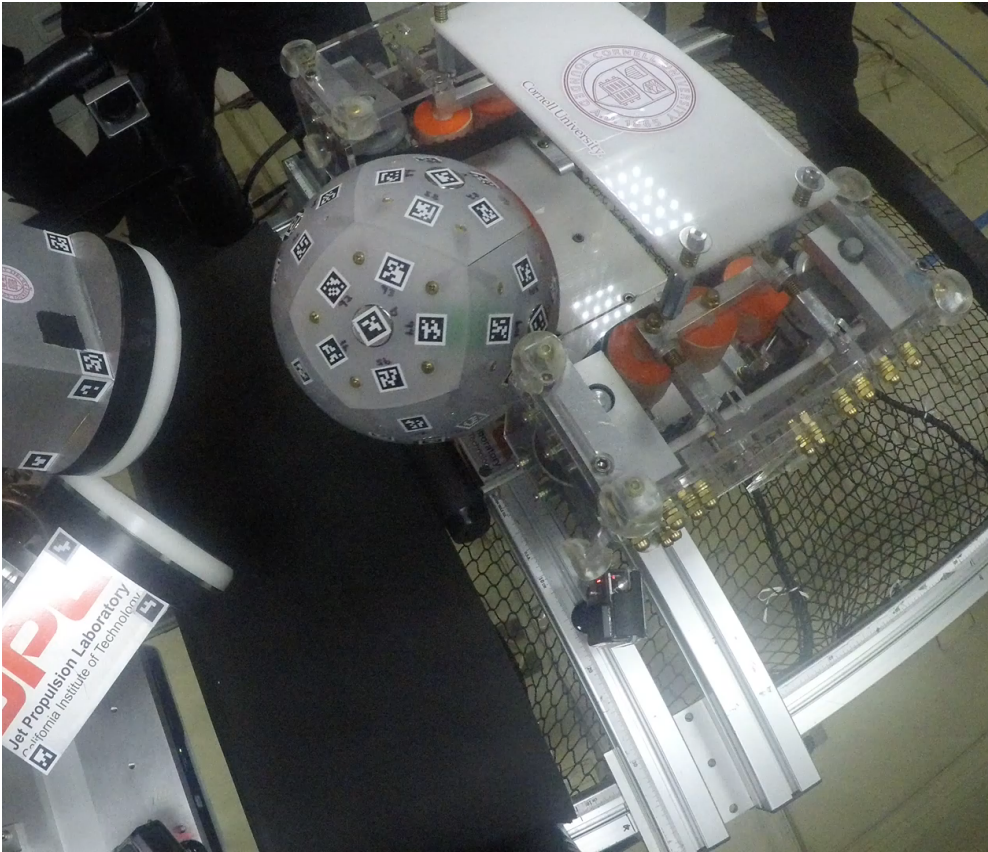
Contact and Escape



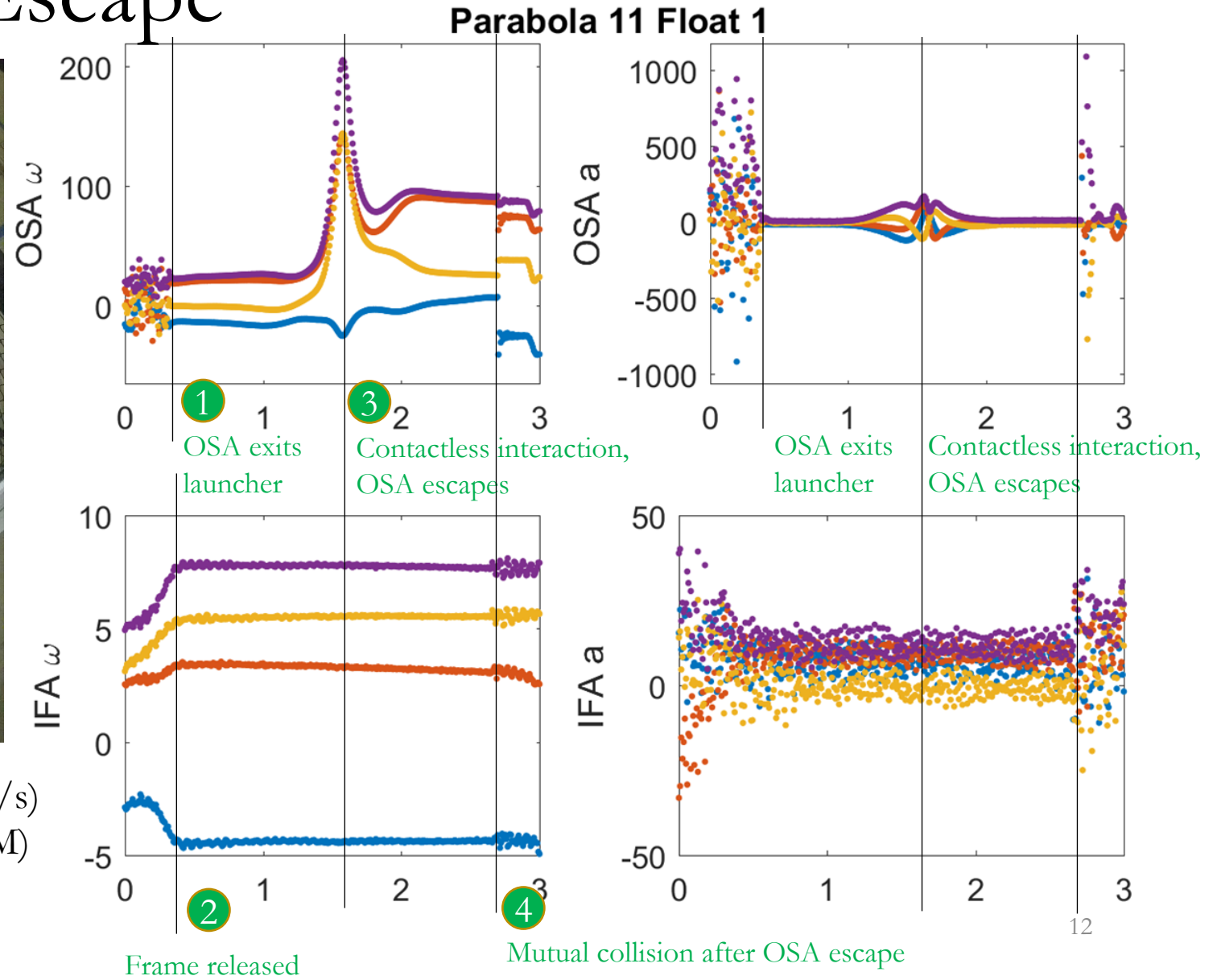
Initial velocity: 13.6 cm/s (> 10 cm/s)
 Initial angular velocity: 3.5 RPM (> 3 RPM)
 Collision force: 21 N



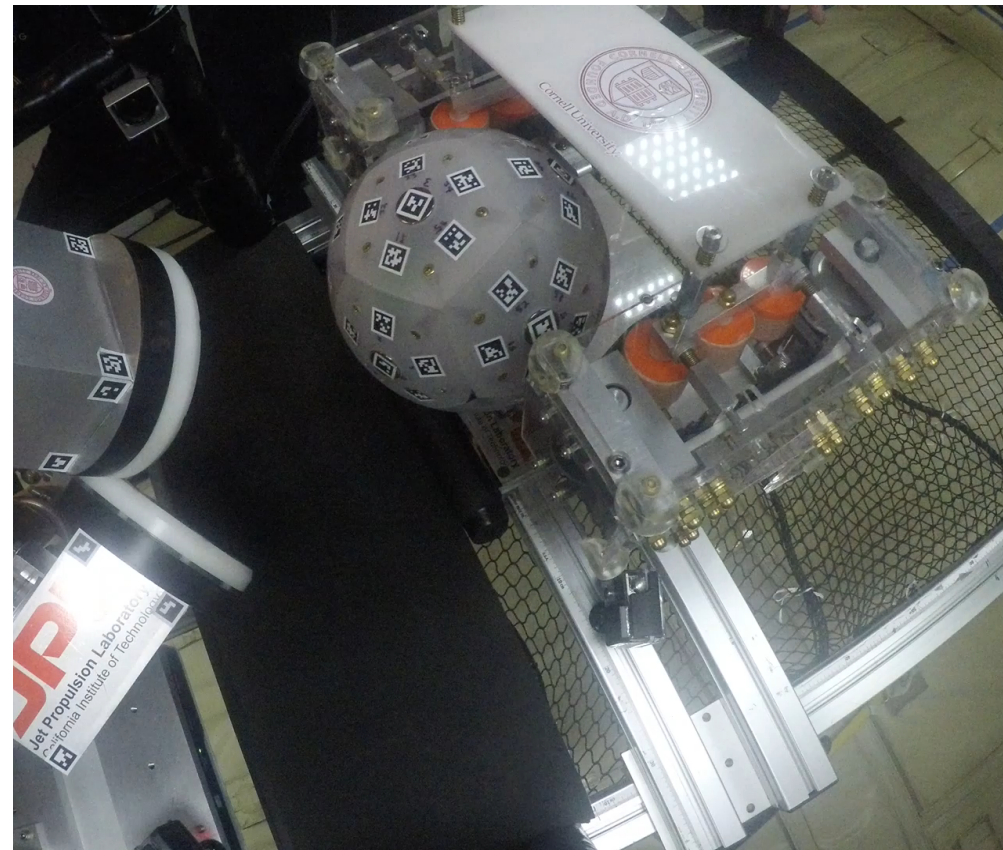
No Contact and Escape



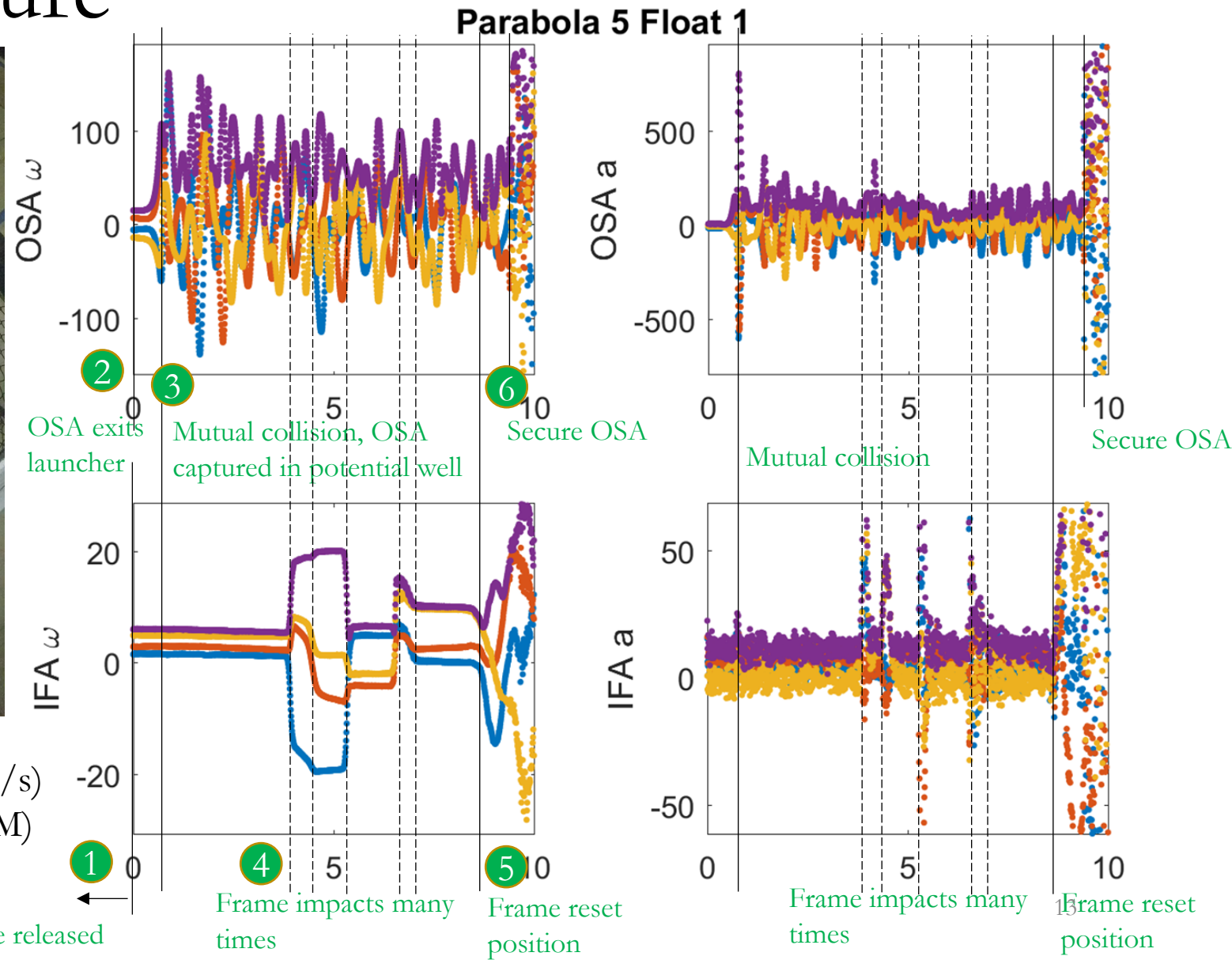
Initial velocity: 26 cm/s (>10 cm/s)
 Initial angular velocity: 3.5 RPM (> 3 RPM)
 Peak force: 3.6 N



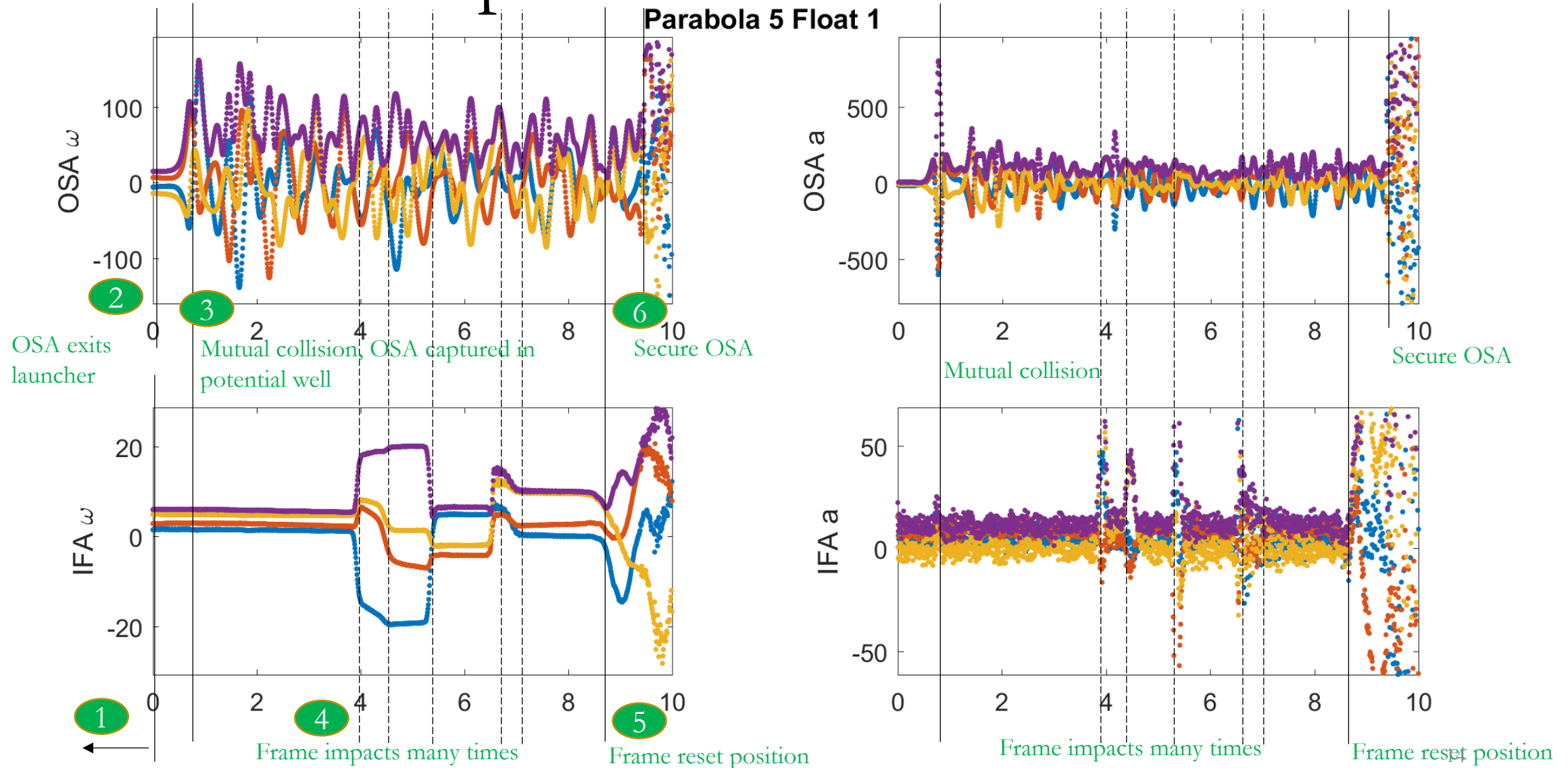
Contact and Capture



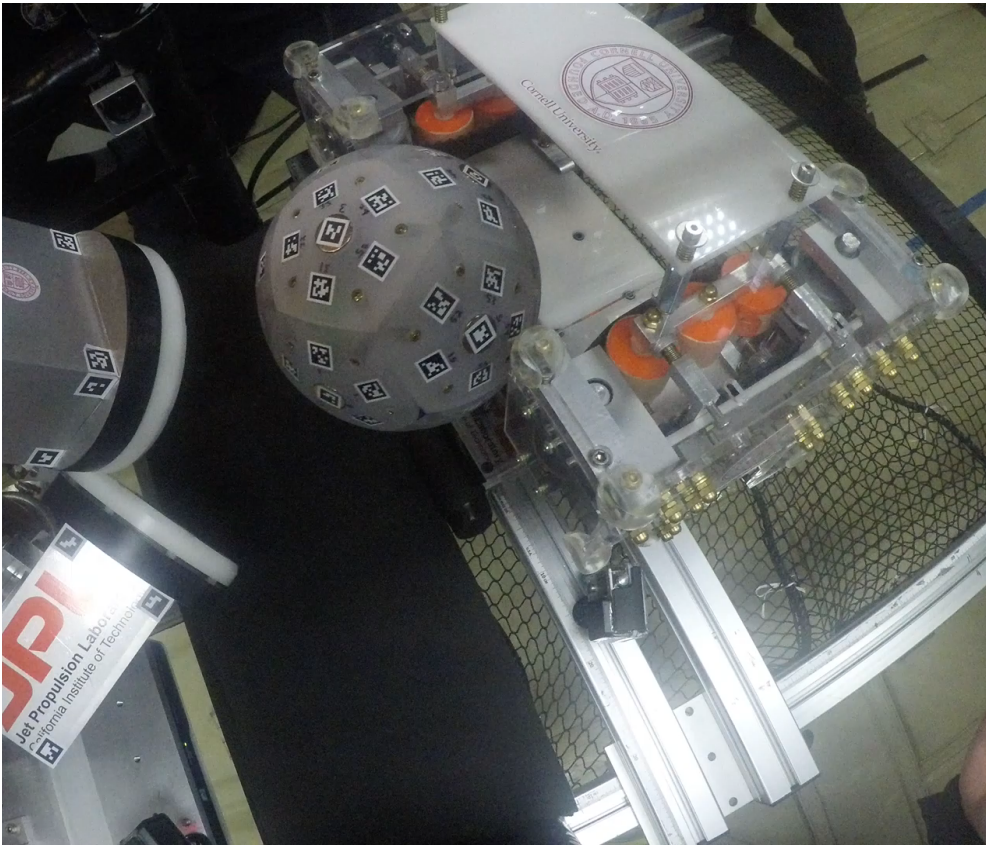
Initial velocity: 22 cm/s (>10 cm/s)
 Initial angular velocity: 2.7 RPM (< 3 RPM)
 Collision force: 16.7 N



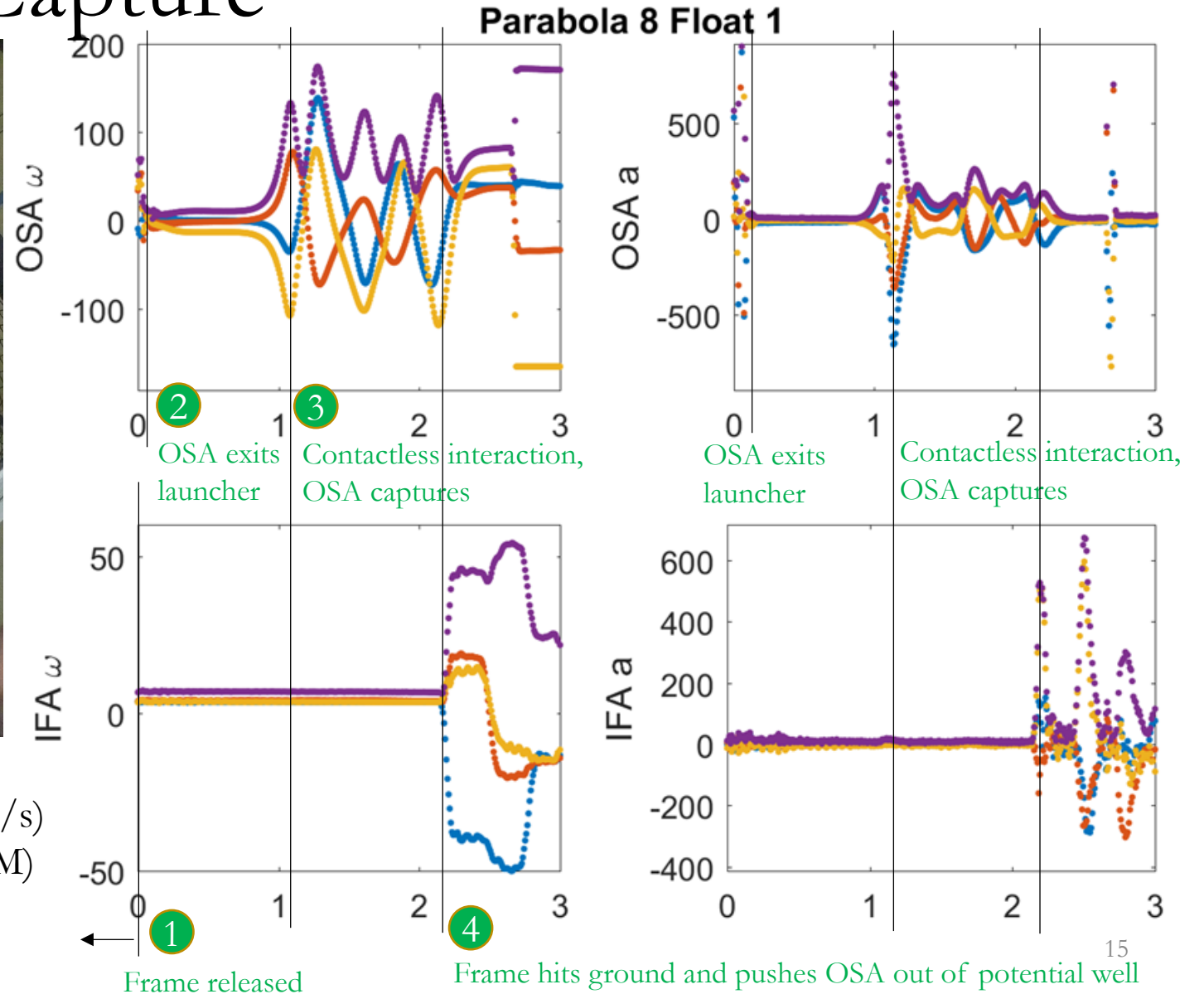
Contact and Capture



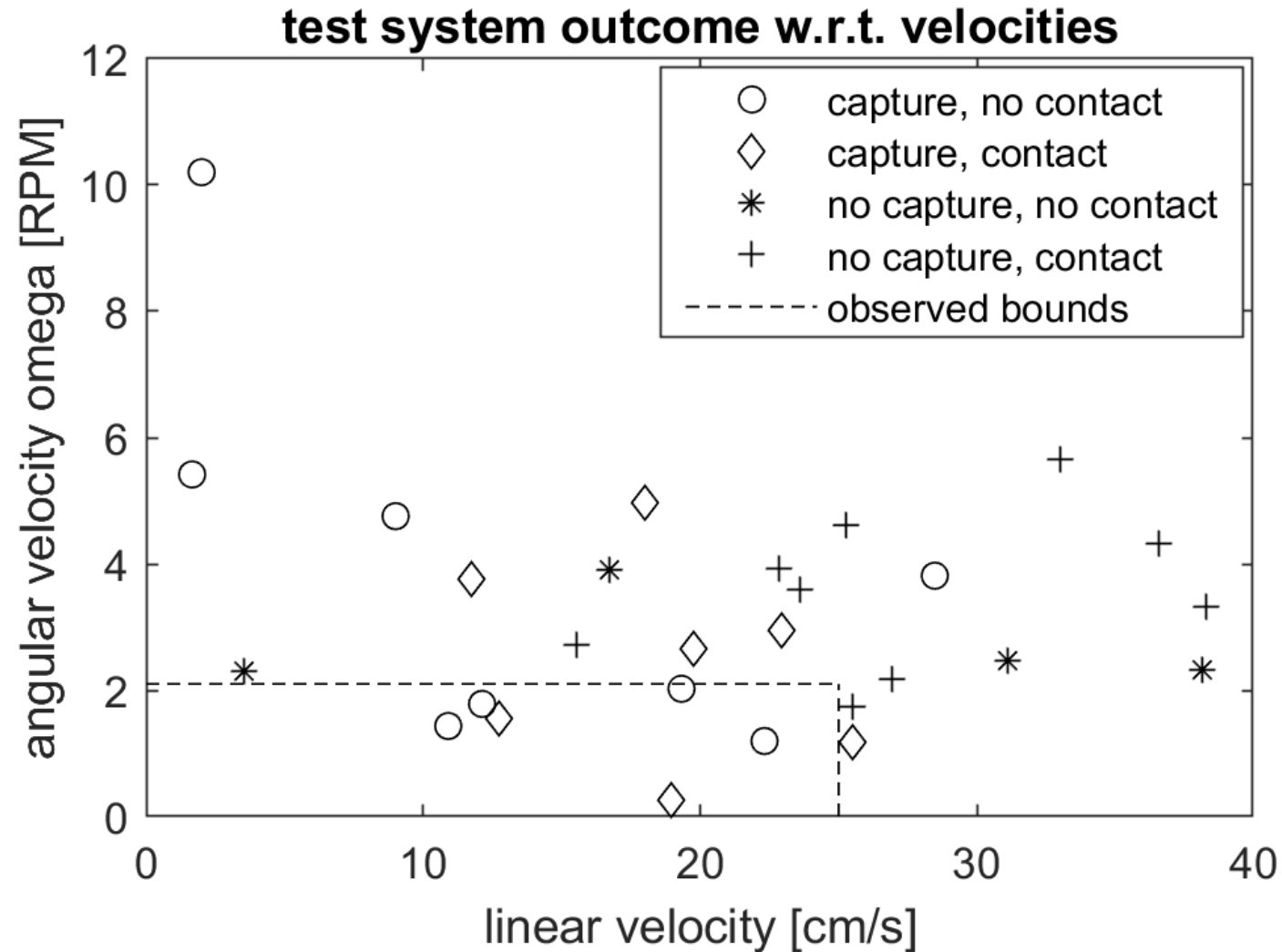
No Contact and Capture



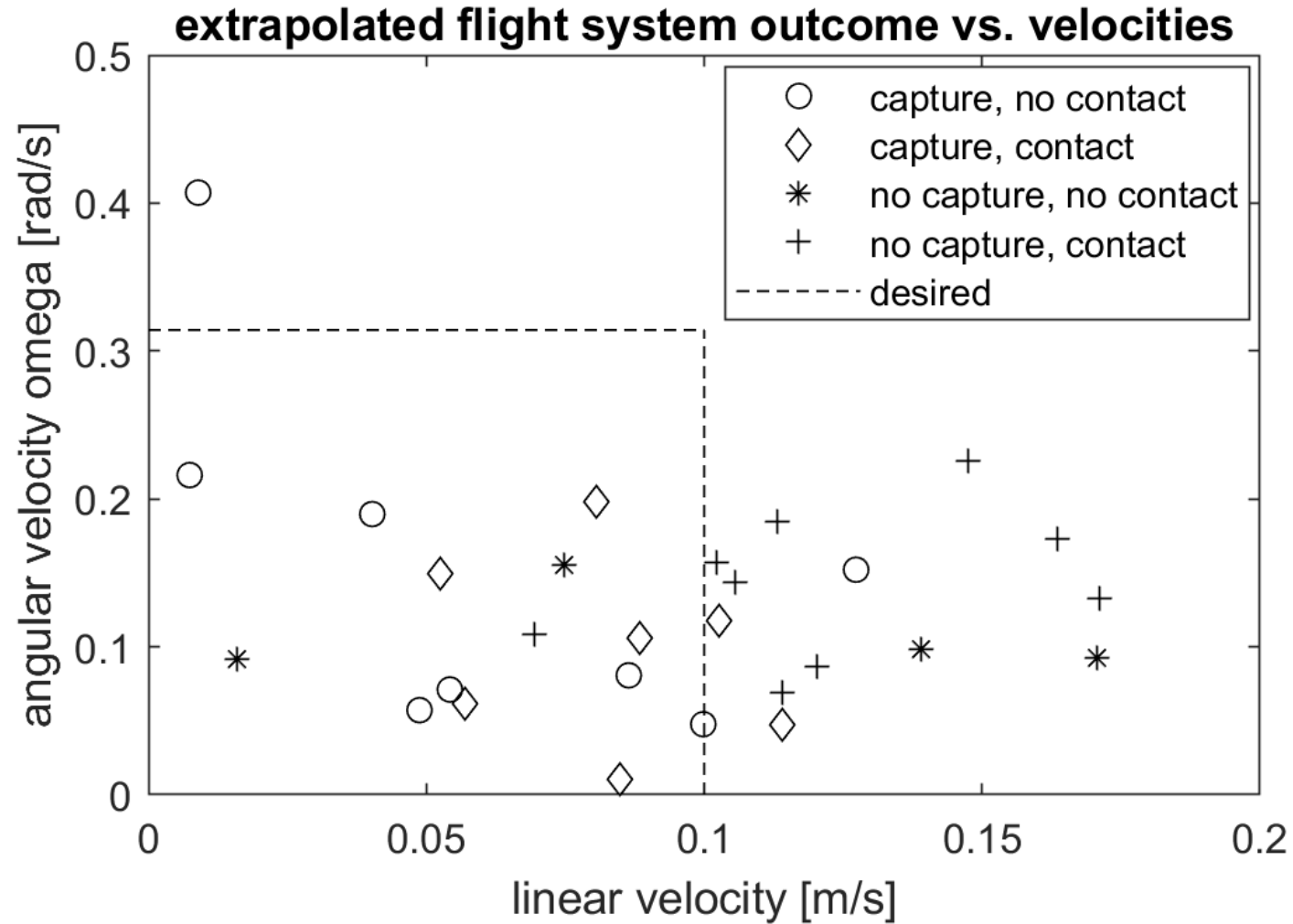
Initial velocity: 7 cm/s (< 10 cm/s)
 Initial angular velocity: 2 RPM (< 3 RPM)
 Peak force: 16 N



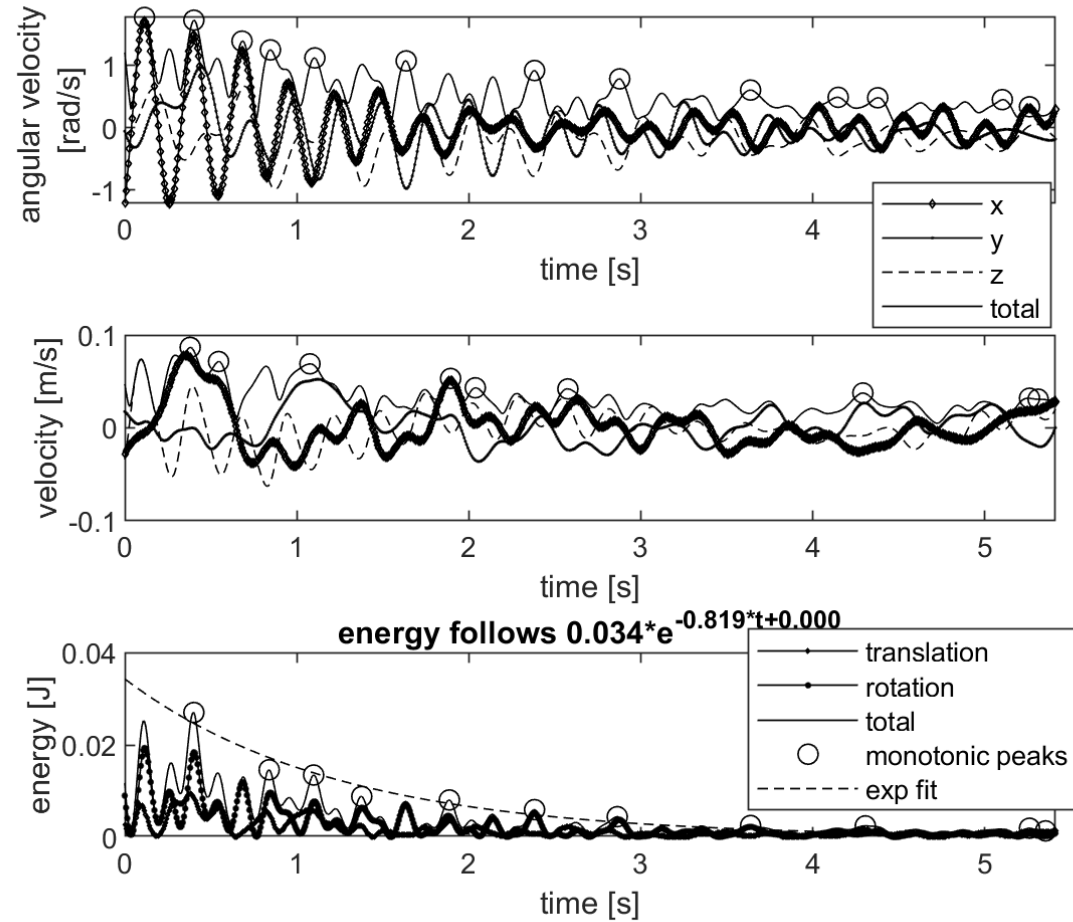
Success Across All Capture Experiments (N=27)



Success Across All Capture Experiments ($N=27$)



Equilibrium Experiment Energy Analysis

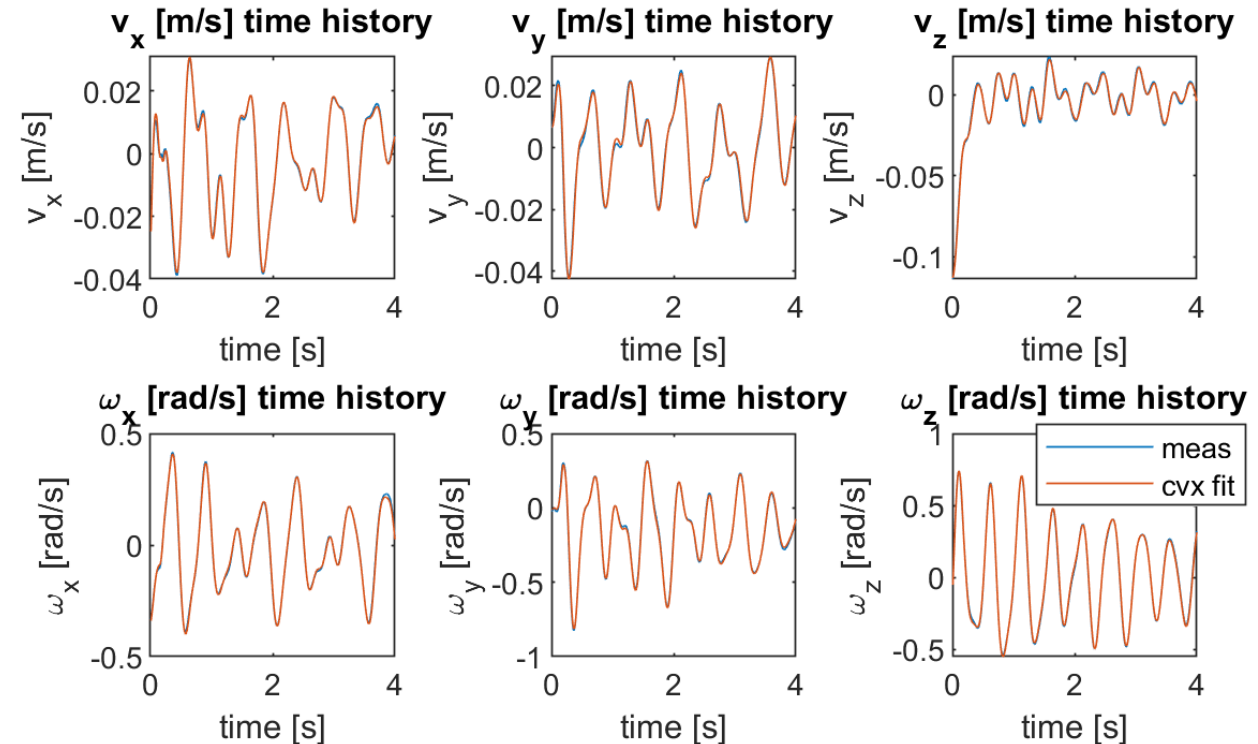


EQ Experiment Stiffness and Damping Analysis

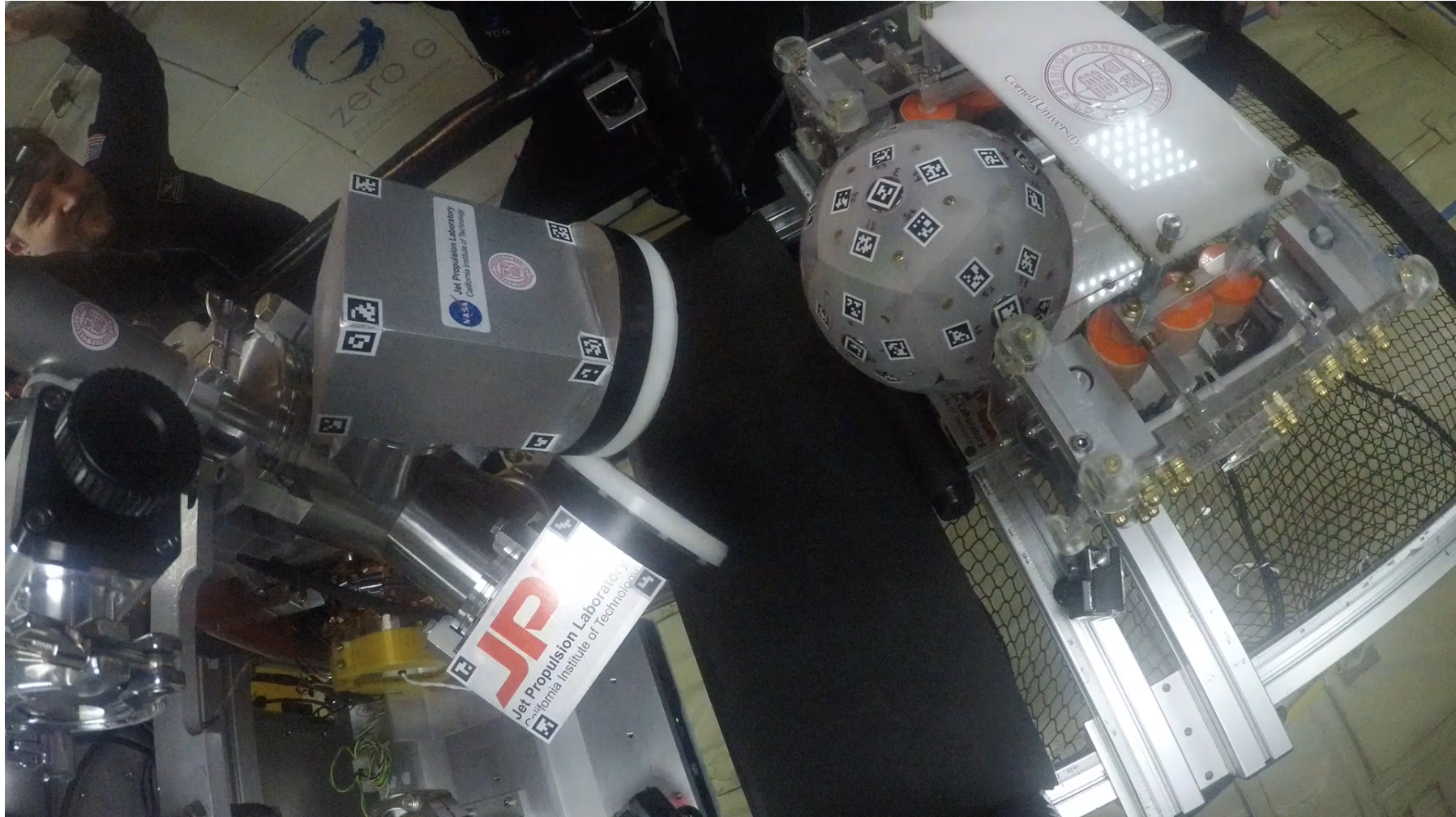
$$\begin{bmatrix} \mathbf{r} \\ \boldsymbol{\theta} \\ \mathbf{v} \\ \boldsymbol{\omega} \end{bmatrix}_{k+1} = \begin{bmatrix} 1_3 & 0_3 & \Delta t 1_3 & 0_3 \\ 0_3 & 1_3 & \Delta t 1_3 & 0_3 \\ -\frac{K_{rr}\Delta t}{M} & -\frac{K_{r\theta}\Delta t}{I} & 1_3 - \frac{C_{rr}\Delta t}{M} & 0_3 \\ -\frac{K_{\theta r}\Delta t}{M} & -\frac{K_{\theta\theta}\Delta t}{I} & 0_3 & 1_3 - \frac{C_{\theta\theta}\Delta t}{I} \end{bmatrix} \begin{bmatrix} \mathbf{r} \\ \boldsymbol{\theta} \\ \mathbf{v} \\ \boldsymbol{\omega} \end{bmatrix}_k$$

(N-m)	K_x	K_y	K_z	K_{θ_x}	K_{θ_y}	K_{θ_z}
E[.]	554	262	108	1.57	0.92	0.88

(sec)	C_x	C_y	C_z	C_{θ_x}	C_{θ_y}	C_{θ_z}
2 % settling time	1.11	0.82	0.44	75	108	84



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